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DIELECTRICS LABORATORY

DIELECTRIC MATERIALS MOISTURE RESISTANCE STUDY

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Fifth Interim Quarterly Report
For The Period February 26, 1954 to May 26, 1954

CONTRACT NO. NObsr -- 63251

Dielectrics Laboratory
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Institute for Cooperative Research
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Contract No. NObsr-63251
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FIFTH INTERIM QUARTERLY REPORT

for the period

February 26, 1954 to May 26, 1954

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ABSTRACT

The effect of tropical exposure on breakdown strength and flashover is reported at this time. The 36 day period running through the month of March was mild. No important deterioration may be reported on the basis of these electrical experiments or those of the Fourth Interim Quarterly Report.

However, plans have been made to receive specimens of various plastic materials after exposure during the future months when greater humidity prevails.

I. Purpose

A. Objective

The objective of this investigation is to determine the degradative effect of moisture on the dielectric materials of this program. The deterioration of electronic equipment in certain natural environments governs the trend of this work. Correlation between natural and simulated conditions, as well as classification of materials, constitutes the goal.

B. Materials

The following materials are to be used in the program. Due to the problems of expense or availability some are mentioned tentatively. The abbreviated designation is included.

1.	(PE)	Polyethylene
2.	(PSQ)	Polystyrene
3.	(CFE)	Monochlorotrifluoroethylene
4.	(PF)	Polytetrafluoroethylene
5.	(PFG)	Polytetrafluoroethylene-glass laminate
6.	(GSG)	Glass silicone Laminate
7.	(MX)	Glass bonded Mica
8.	(MFE)	Mica-filled Phenolic Resin (molded)
9.	(MDAP)	Mineral filled Diallyl Phthalate Resin (molded)
10.	(MCM)	Cellulose-filled Melamine Resin (molded)

C. Properties to be Studied

Since an important part of the objective pertains to the practical application of electronic equipment, the following types of tests will be applied, at such intervals, and on such materials as to seek a practical end.

1. Surface resistivity d.c.
2. Volume resistivity d.c.
3. Dielectric constant 60 cycles, 1 kc, and 2 mc.
4. Dissipation factor 60 cycles, 1 kc, and 2 mc.
5. Dielectric strength 60 cycles, 2 and 100 mc.
6. Surface flashover 60 cycles, 2 and 100 mc.

In the case of some materials, practical interest might be satisfied rather quickly. However, it does not follow that all points of academic interest will be satisfied at that time.

D. Time of Exposure

1. Initially
2. The samples are to be aged at a tropical site, and studies made up to one year. Some samples are to be left at this location for an indefinite period.

3. It would seem that at least four points would be required to determine a trend. The number of measurement periods will depend upon the rate of deterioration, continued interest in a particular material, and the overall coordination of our effort with the tropical laboratory.

II. Publications and Reports

A. Final report of Contract DA-36-039-sc-90

B. Quarterly Progress Reports (First, Second, Third, Fourth, Fifth, Sixth and Seventh) of Contract DA-36-039-sc-42478

C. Final Report of Contract NObsr-45372

D. Interim Quarterly Progress Reports (First, Second, Third and Fourth) of Contract NObsr-63251

III. Factual Data

A. High Voltage Puncture Tests

In the previous Interim Quarterly Report, results of various tests were given upon materials that had been exposed to tropical conditions. The breakdown puncture comparison was withheld until this time, so as to study the data. It was obvious that no serious change had occurred in the breakdown strength of the materials, but even the initial values before exposure are subject to some spread and the detection of slight change required closer inspection. The main part of the work was sample preparation, initial evaluation, arrangement of exposure schedule, shipment of samples, and coordination of effort. This had all been accomplished by February and the samples were placed upon exposure at sites 1 and 2. They were exposed for a period of 36 days running through the month of March.

This is the mild period of the year in the region of Coco Solo and some of the materials inspected for breakdown strength were known to be moisture resistant, so the fact that little damage may be reported is not surprising.

However, a material designated as #400, an asbestos filled molded phenolic, not of the program, was sent to the tropical sites because it was known to pick up moisture. In Table I, the 60-cycle breakdown strength shows considerable decrease after exposure at both tropical sites. This proves that at least highly susceptible materials suffer during this mild period.

In the previous Interim Quarterly Report, material #400 was shown to have gained weight due to exposure at both tropical sites. Of course during the months to follow, it may be expected that the more moisture resistant materials will also be adversely affected. Direct current and Qmeter measurements indicated some adverse effects in the case of #400 material shown by the data of the previous Interim Quarterly Report.

The GSG material, according to the data of Table I shows a decrease in 60-cycle breakdown strength after exposure at both tropical sites. The decrease is noticeable at 60-cycles, but not evident in the case of breakdown tests at 2-megacycles or 100-megacycles. In the previous Interim Quarterly Report, the dissipation factor as determined by Qmeter measurements at 1-megacycle showed some evidence of tropical deterioration. From the work of Contract DA-36-039-sc-42478, it has been proven that low frequency breakdown strength measurements show effects due to moisture absorption more readily than higher frequency tests. The effect of these 36 days of exposure on GSG material must be considered slight.

The results of breakdown tests on PE material are given in Table I, before and after exposure. In keeping with the data of the previous Interim Quarterly Report, we may conclude that none of the properties measured indicate any deterioration.

The same conclusion is reached regarding PF material. Both PE and PF materials have been examined under severe ICR conditioning (Contract DA-36-039-sc-42478) previously and moisture alone would not be expected to produce adverse electrical effects. These two materials need only be tested after rather long intervals, because it is unlikely that tropical exposure will affect them adversely.

During the next month, some specimens are due back at ICR. The material GSG will be examined again to see if the increasing severity of the season produces greater evidence of deterioration. MX, PSQ and PFG materials will also be examined at this time. These are considered to be good electrical materials, but by the time of recall, they will have suffered considerable exposure.

Some idea of the decrease of breakdown strength will be gained by conditioning tests at ICR. However, on the basis of present knowledge, MFE, MCM and MDAP materials are not expected to hold up electrically beyond August at the tropical sites.

CFE material may also be affected at a rapid rate during July and August.

Table II gives the initial evaluation of breakdown strength for the materials of the program. Different types of electrodes are used depending upon the nature of the materials. The materials that were readily molded employ a recessed metalized cavity of 3/4" diameter with a flat bottom. The thickness under the flat region is 50 or 60 mils and this determines the voltage level required for breakdown. The MFE, MDAP, MCM, MX and PSQ materials were provided with such molded cavities. Some of the other materials are received as 1/2" thick sheet stock from the manufacturer and require that cavities be drilled into them leaving a suitable thickness under the inserted electrode. A standard 1/2" twist drill is used to make a most convenient type of cavity. PE, PF and PFG specimens are prepared in this manner and tested at 30 mils thickness. The relative merits of the molded flat bottom cavity and the tapered bottom one formed with a 1/2" standard drill were discussed in the previous Interim Quarterly Report.

The CFE material has posed a special problem, it is very expensive and due to various manufacturing delays and decisions, the 1/2" stock will be entering the program late. However, 1/8" stock was sent to the tropical sites sometime ago. Therefore, in order to get some breakdown information soon on this material, a special procedure has been developed whereby a recessed cavity may be made in the 1/8" stock. A standard 1/4" drill is used to form the cavity and the thickness at the breakdown region is set at 15 mils. With 1/8" stock and 1/4" drilled cavity, performance is similar to that with the 1/2" drilled cavity, except the 60-cycle test requires grading with semi-conducting rescon cloth on the surface near the cavity.

Table II gives the initial dielectric strength of the materials with the most suitable electrode and breakdown thickness. This table is still the subject of some further work, the typical spread for each material at 60-cycles, 2-megacycles and 100-megacycles must be ascertained in order to later evaluate the seriousness of any change that takes place at the tropical sites.

It is important to add that some samples of the same materials are being conditioned at high humidity at ICR. These results will be reported after a suitable period.

B. Flashover Tests

Table III shows the value of flashover strength at 60-cycles, 2-megacycles and 100-megacycles for several materials of the program. The initial values are given and also the values after exposure during the month of March at the tropical sites.

Both sites fail to produce any permanent change in the flashover strength of the materials examined. Such deviations as occur are within the normal spread of results. It is possible, that momentary lower values of flashover strength might be obtained at the tropical sites. However, the material would have to be badly deteriorated to persistently show a low value back at the ICR atmosphere after transhipment.

C. Nature of Tropical Exposure Sites

Both sites are located at Coco Solo, Canal Zone, site 1 is inside of a closed, corrugated iron shed completely covered with jungle where normally, during two thirds of the year, the humidity is high. Site 2 is a Quonset Hut, open-ended but screened, placed on a concrete slab in a clearing.

D. Measurement of Dielectric Constant and Dissipation Factor with ICR Conditioning

(1) Schering Bridge Measurements

In the Fourth Interim Quarterly Report, tabular results were given to show the effect of laboratory conditioning of materials. Such exploration very probably will indicate in a qualitive way the performance of materials at tropical sites during the wet season. At 60 and 1000-cycles, the dielectric constant and dissipation factor of PFG and PSQ are not affected to a measurable extent, DWG 233 and DWG 235. The glass bonded mica material, MX, appears to show a steady gain in the value of dissipation factor at this severe condition of 25°C and 100% R.H. The sharp initial increase in the value of dielectric constant is subject to some question however. This effect may in part be due to surface conductivity which increases the effective size of the electrodes. It was noticed that the surface of this material wets and forms a highly conducting film when exposed to high humidity. In fact a few specimens of MX were allowed to dry in air after previous long time exposure to 25°C and 100% R.H. atmosphere. The dielectric constant quickly returned to its initial value, but the dissipation factor remained high.

The CFE material apparently is badly affected after 60 days at 25°C and 100% R.H., both dielectric constant and dissipation factor show significant increase.

It is important to point out here, that PE, PF and PSQ materials appear not to absorb water and the volume measurements of dielectric constant and dissipation factor remain favorable. Further the surface of these materials exhibit no conduction even at high humidity as long as they are clean.

By contrast, some other materials hold up with reference to volume properties, but high humidity quickly reduces the surface resistance to a few megohms per square. This unfavorable surface wetting in an atmosphere of high humidity is very evident in the case of GSG, PFG and MX materials; it also is evident in the case of ordinary glass.

(2) Beechnut Measurements

At 2, 18 and 100-megacycles, additional measurements were made as materials were conditioned at 25°C and 100% R.H. An inspection of the dielectric constant and dissipation factor curves (DWG 234 and DWG 236) leads to the same conclusions as at 60-cycles and 1000-cycles. At the lower frequencies, the effects are more readily detected.

IV. Conclusions

A. The measurements regarding dielectric strength reported at this time are consistent with the observations made in the previous Interim Quarterly Report.

B. Extensive flashover tests on exposed samples indicated that the month of March produced no significant surface damage.

V. Program for the Next Interval

A. Returning specimens from the tropical sites will provide a full testing schedule.

B. Evaluation of specimens, after exposure to 25°C and 100% R.H. at ICR, will yield further important data.

VI. Identification of Personnel

John J. Chapman	Research Contract Director, Doctor of Engineering in Electrical Engineering, two-thirds time.
Louis J. Frisco	Assistant Research Contract Director, Master of Engineering in Electrical Engineering, two-thirds time.
Julian S. Smith	Research Staff Assistant, Bachelor of Engineering in Electrical Engineering, full time.
Frederick L. Schaff	Laboratory technician, full time
Edward A. Szymkowiak	Laboratory technician, one-half time.
Richard D. Picard	Laboratory technician, one-half time.
Carol E. Marino	Secretary, one-half time.

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Appendix i

VII Tables

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Table I

Comparison of Breakdown Strength before and after Exposure at the Tropical Sites

Material	Site	Condition	Frequency	VPM
GSG	ICR	Initial	60-cycles	450
GSG	1	36 Days	60-cycles	400
GSG	2	36 Days	60-cycles	400
GSG	ICR	Initial	2-MC	150
GSG	1	36 Days	2-MC	150
GSG	2	36 Days	2-MC	150
GSG	ICR	Initial	100-MC	55
GSG	1	36 Days	100-MC	55
GSG	2	36 Days	100-MC	55
PE	ICR	Initial	60-cycles	1345
PE	1	36 Days	60-cycles	1300
PE	2	36 Days	60-cycles	1300
PE	ICR	Initial	2-MC	460
PE	1	36 Days	2-MC	430
PE	2	36 Days	2-MC	430
PE	ICR	Initial	100-MC	110
PE	1	36 Days	100-MC	110
PE	2	36 Days	100-MC	110
PF	ICR	Initial	60-cycles	1170
PF	1	36 Days	60-cycles	1150
PF	2	36 Days	60-cycles	1175
PF	ICR	Initial	2-MC	407
PF	1	36 Days	2-MC	410
PF	2	36 Days	2-MC	400
PF	ICR	Initial	100-MC	160
PF	1	36 Days	100-MC	160
PF	2	36 Days	100-MC	160
#400	ICR	Initial	60-cycles	841
#400	1	36 Days	60-cycles	490
#400	2	36 Days	60-cycles	450

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Table II

Initial Values of Dielectric Strength
in Volts Per Mil

Material	Type of Electrode	Thickness	60-cycle	2-MC	100-MC
MFE	Molded Cavity 3/4" Diam.	60 Mils	930	38	9.5
MDAP		60 Mils	720	22	4.7
MCM		60 Mils	810	22	5.2
MX		60 Mils	760	99	46
PSQ		50 Mils	1415	357	111
GSG	Drilled Cavity 1/2" Drill	60 Mils	450	150	55
PE		30 Mils	1345	160	110
PF		30 Mils	1170	407	160
PFG		40 Mils	930	320	120
CFE	Drilled Cavity 1/4" Drill	15 Mils	2007	150	55

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Table III

Flashover Values

Material	Frequency	Initial KV	After Exposure KV
MX	60-cycles	9.2	9.4
PF	60-cycles	15.5	14.2
PE	60-cycles	13.1	15.2
PSQ	60-cycles	13.2	11.1
GSG	60-cycles	9.1	8.5
MX	2-MC	7.5	6.6
PF	2-MC	9.1	10.7
PE	2-MC	11.0	12.4
PSQ	2-MC	10.5	10.1
GSG	2-MC	9.0	9.2
MX	100-MC	9.4	9.6
PF	100-MC	11.0	13.8
PE	100-MC	13.5	14.2
PSQ	100-MC	9.8	10.0
GSG	100-MC	8.4	10.8

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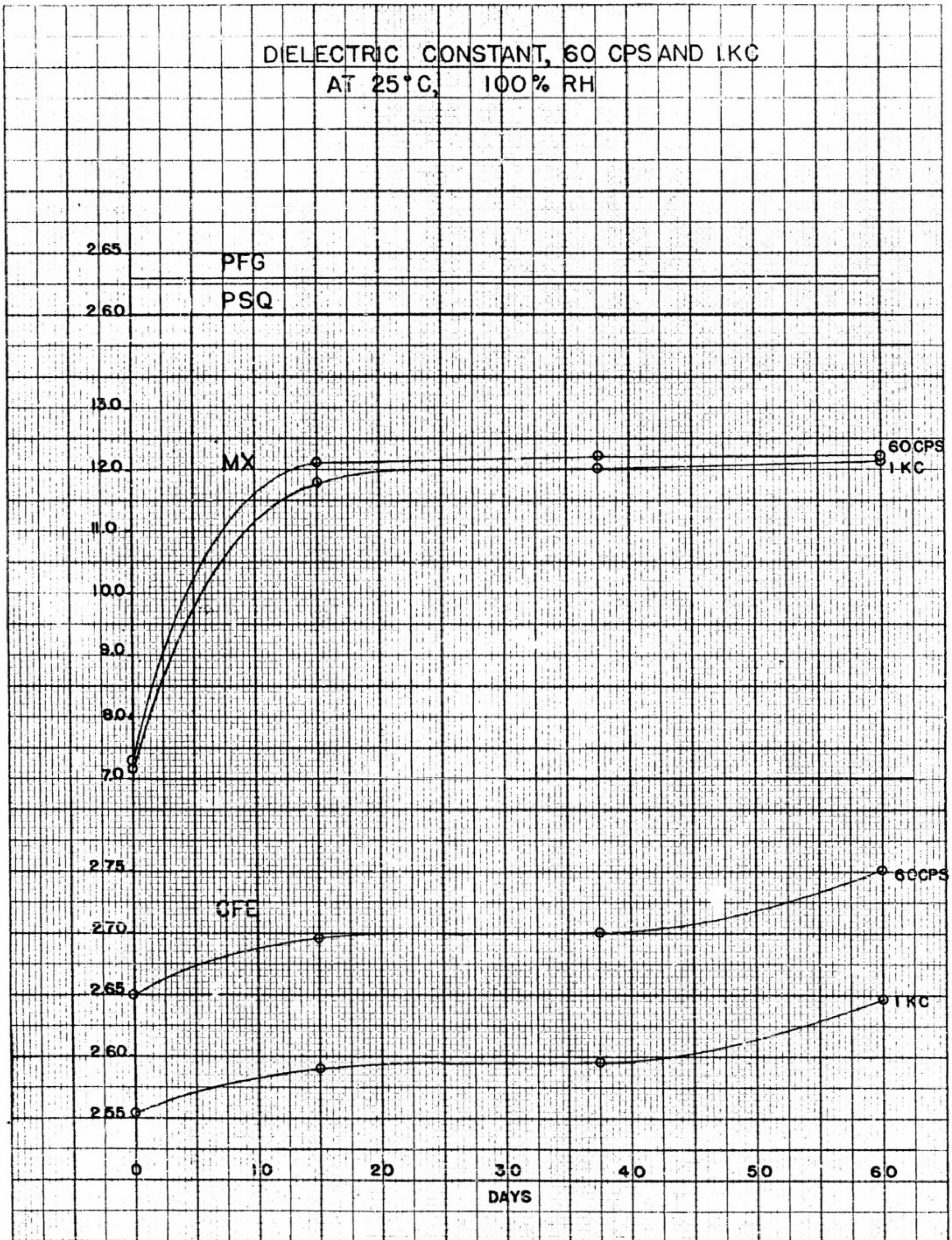
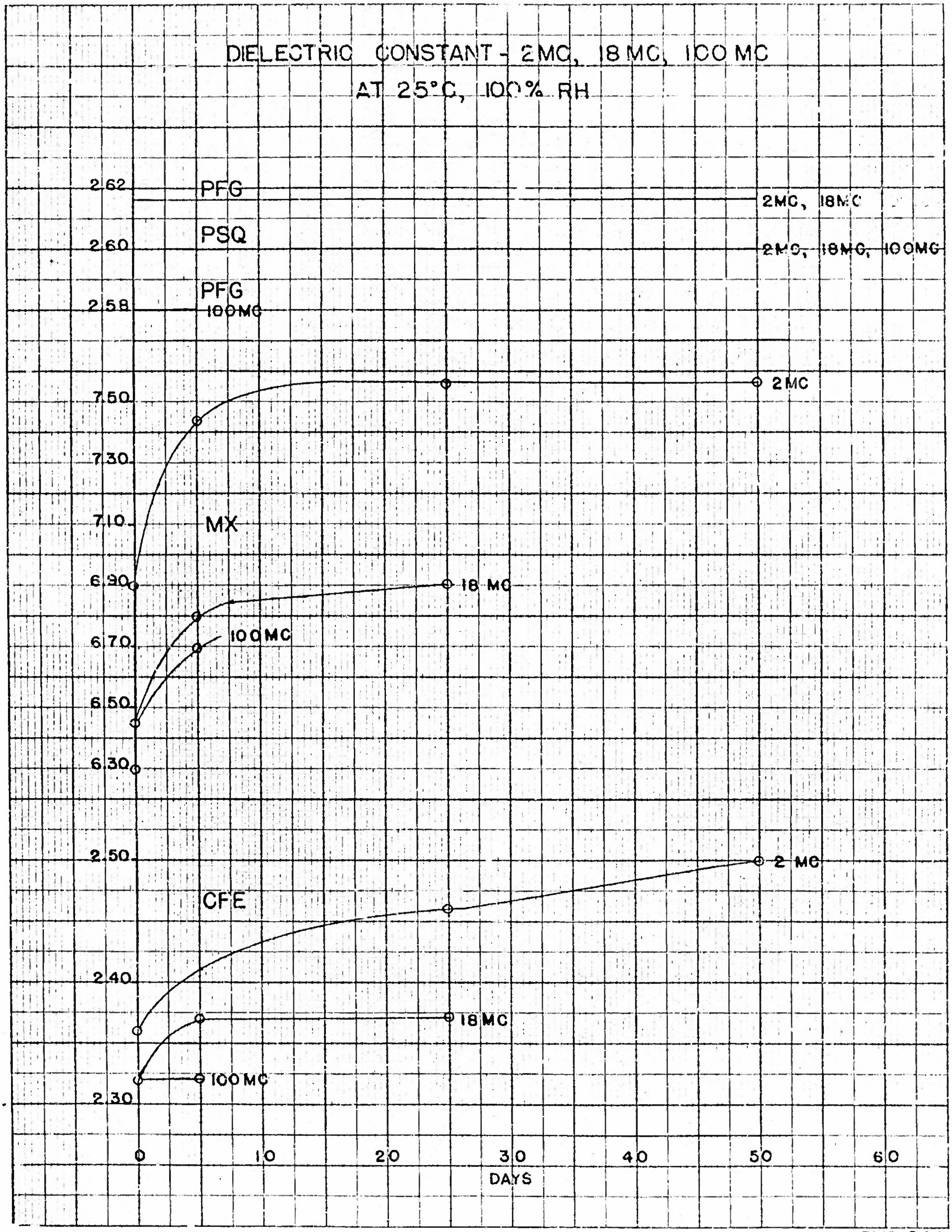
Appendix ii

VIII **Graphs and Drawings**

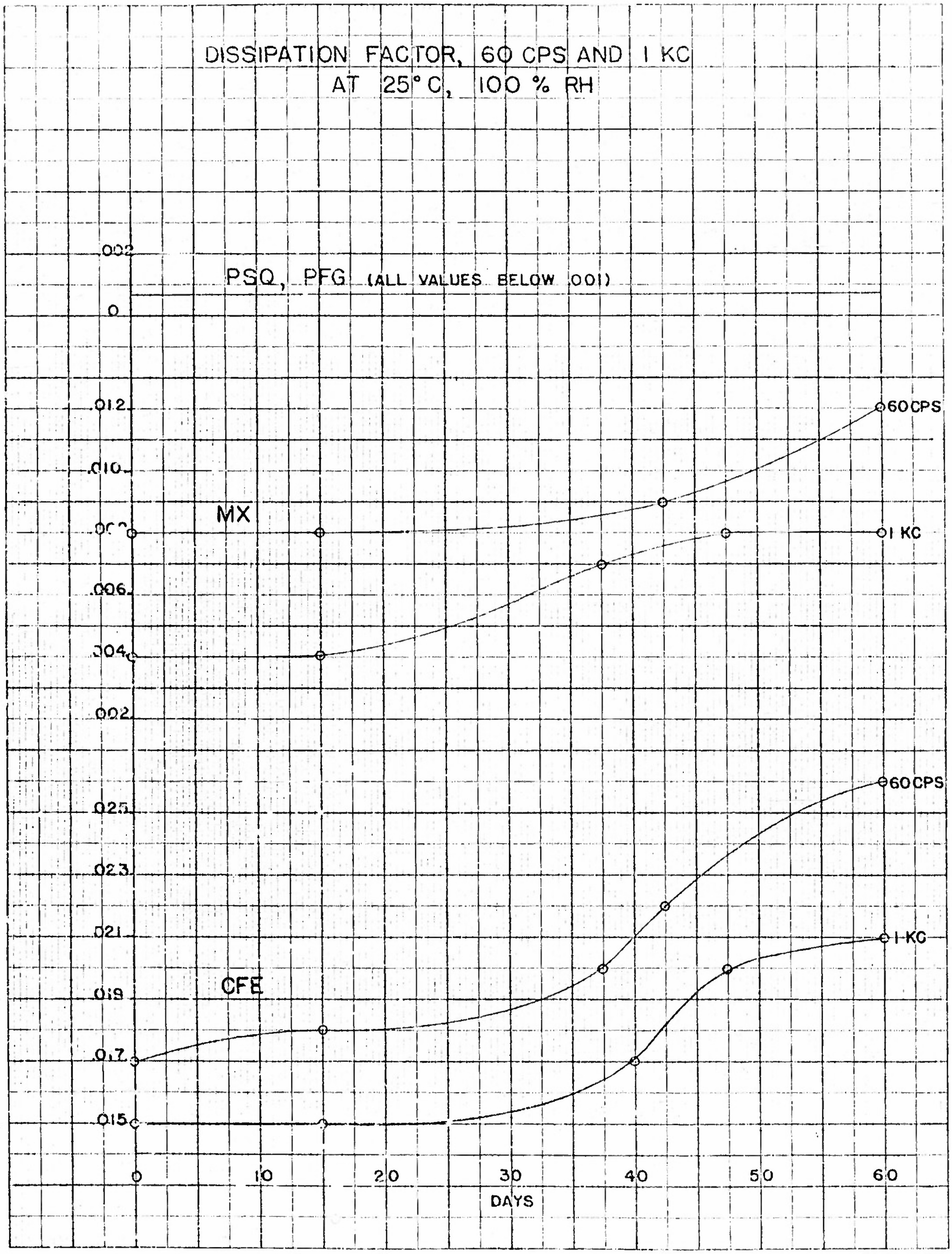
DWG 233	Dielectric Constant, 60 and 1000-cycles after exposure to 25°C and 100% R.H.
DWG 234	Dielectric Constant, 2, 18 and 100-megacycles, after exposure to 25°C and 100% R.H.
DWG 235	Dissipation Factor, 60 and 1000-cycles, after exposure to 25°C and 100% R.H.
DWG 236	Dissipation Factor, 2, 18 and 100-megacycles, after exposure to 25°C and 100% R.H.


DIELECTRIC CONSTANT, 60 CPS AND 1KC
AT 25°C, 100% RH
PFG
PSQ
MX
GFE
60 CPS
1 KC
60CPS
1 KC
2.65
2.60
13.0
12.0
11.0
10.0
9.0
8.0
7.0
2.75
2.70
2.65
2.60
2.55
0
10
20
30
40
50
60
DAYS

DWG 233

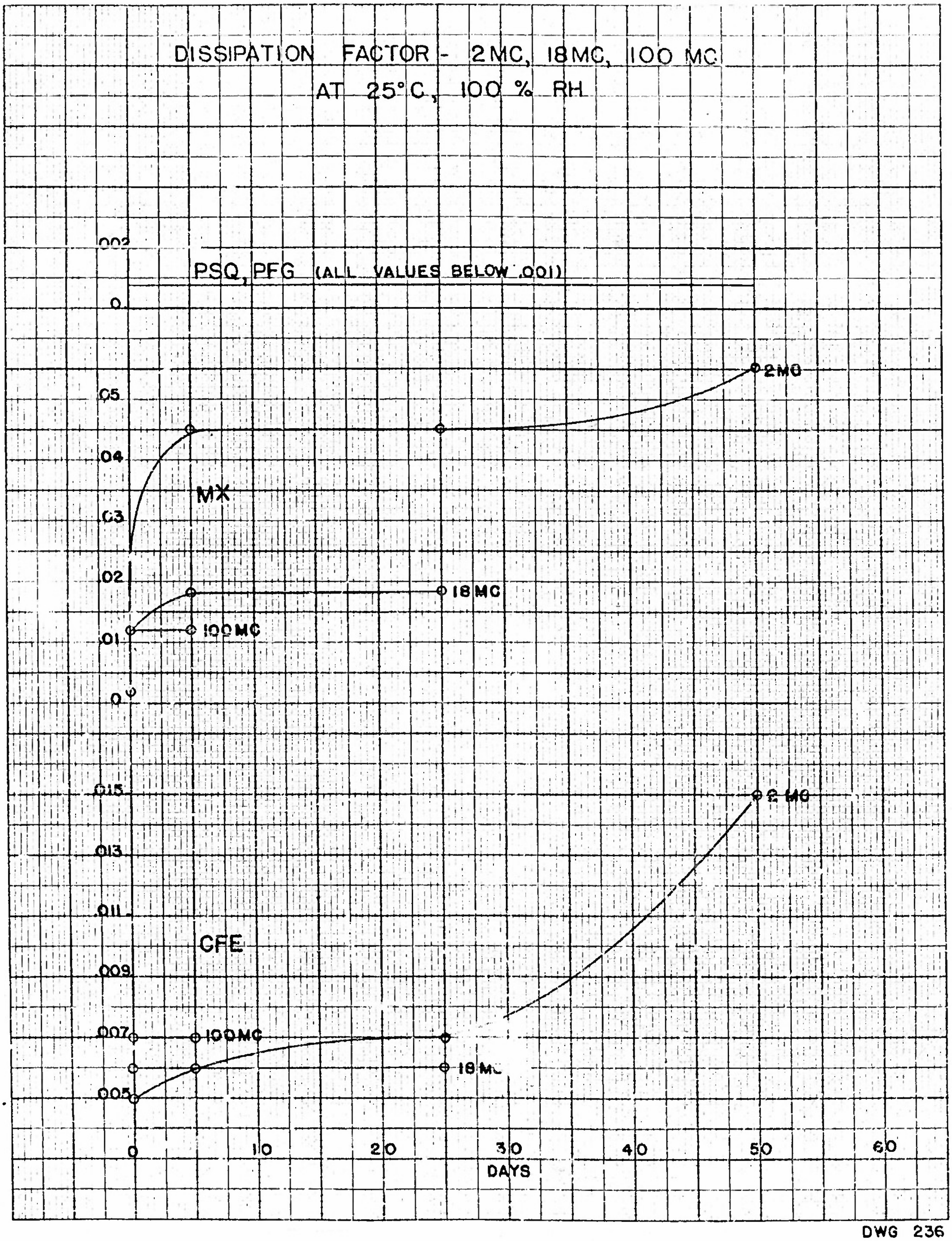

DIELECTRIC CONSTANT - 2MC, 18 MC, 100 MC
AT 25°C, 100% RH
PFG
2MC, 18MC
PSQ
2MC, 18MC, 100MC
PFG
100MC
2MC
MX
18 MC
100MC
CFE
2 MC
18MC
100MC
2.62
2.60
2.58
7.50
7.30
7.10
6.90
6.70
6.50
6.30
2.50
2.40
2.30
0
10
20
30
40
50
60
DAYS

DWG 234



DISSIPATION FACTOR, 60 CPS AND 1 KC
AT 25° C, 100 % RH
.002
PSQ, PFG (ALL VALUES BELOW .001)
0
.012
.010
.008
.006
.004
.002
MX
60 CPS
1 KC
.025
.023
.021
.019
.017
.015
CFE
60 CPS
1 KC
0
10
20
30
40
50
60
DAYS

DWG 235


DISSIPATION FACTOR - 2MC, 18MC, 100 MC
AT 25°C, 100 % RH
PSQ, PFG (ALL VALUES BELOW .001)
MX
2MC
18MC
100MC
CFE
2 MC
100MC
18MC
DAYS
DWG 236